A STUDY OF HYBRID VIGOR IN A CROSS BETWEEN POLAND CHINA AND DUROC JERSEY SWINE[1]

By E. ROBERTS, *professor of animal genetics*, and W. E. CARROLL, *professor of swine husbandry, Department of Animal Husbandry, Illinois Agricultural Experiment Station*

INTRODUCTION

Cross-breeding has been used for the purpose of recombining the best characteristics of two or more breeds in the formation of a new breed. This is a process that requires many years of continued selection. A second purpose in cross-breeding is to obtain immediate offspring possessing more desirable characteristics, such as greater size, more economical feed utilization, or more rapid growth, than are exhibited by either parental breed.

Interest in cross-breeding for the production of market animals has been of long duration and at the present time is greater in the United States than it has been for decades. The recent success in the production of hybrid corn may have been a stimulating factor in this interest.

The purpose of this experiment was to study the effect of cross-breeding on weight of pigs at birth, vigor, rapidity of growth, and economy of gain.

BREEDS AND METHODS

Duroc Jersey and Poland China breeds were used. Double matings were made according to the following system:

$$\text{Duroc Jersey sow} \times \begin{cases} \text{Duroc Jersey boar} \\ \text{Poland China boar} \end{cases}$$

$$\text{Poland China sow} \times \begin{cases} \text{Duroc Jersey boar} \\ \text{Poland China boar} \end{cases}$$

The two boars were usually mated to the same sow with as little time elapsing between the two services as possible. The same two boars in any one season were mated to all sows. The order of service of the two boars was alternated in order to eliminate the possibility of order of mating affecting the kind of offspring produced.

During gestation the sows were given similar feed and care which were considered to be adequate. After farrowing, the mothers and litters were handled in accordance with the McLean County swine-sanitation system, all receiving similar feed and care.

All pigs were weighed and given individual earmarks at birth, later immunized against hog cholera, and the boar pigs castrated. At weaning or soon thereafter the pigs were separated into the following groups: Purebred Duroc Jersey; purebred Poland China; crossbred pigs from Duroc Jersey female × Poland China male; and crossbred pigs from Poland China female × Duroc Jersey male.

The various groups of pigs were fed, in dry lots, shelled corn and a protein supplemental mixture in separate compartments of self-feeders. The supplemental mixture consisted of 2 parts tankage, 1

[1] Received for publication May 8, 1939.

part linseed meal, and 1 part alfalfa meal. The pigs were kept on this ration until they reached an approximate weight of 200 pounds.

Weights of pigs were taken at birth, when put into lots, and every 2 weeks thereafter until final weight was reached. Records of feed consumption by groups were also kept.

TABLE 1.—*Relation of time elpasing between services in double-mated sows and parentage of litters*

Interval between services (minutes)	Matings	Litters sired by—			Interval between services (minutes)	Matings	Litters sired by—		
		First boar only	Second boar only	Both boars			First boar only	Second boar only	Both boars
	Number	*Number*	*Number*	*Number*		*Number*	*Number*	*Number*	*Number*
1	12	3	1	8	15	1	0	1	0
2	22	1	5	16	18	1	0	0	1
3	9	3	0	6	20	1	0	0	1
4	10	2	2	6	25	1	0	1	0
5	12	3	2	7	240	1	1	0	0
6	5	2	0	3	480	1	0	1	0
7	1	0	1	0	540	1	0	1	0
8	2	2	0	0	720	1	0	1	0
10	3	1	1	1	960	1	1	0	0
12	1	0	0	1					
					Total	86	19	17	50

EFFECT OF TIME BETWEEN SERVICES ON PARENTAGE OF YOUNG

The time elapsing between services by the two boars varied from 1 minute to 16 hours, though the majority of double matings were made within a 6-minute interval (table 1). The litter produced in the case of the 16-hour interval was sired entirely by the first boar. The next longest time elapsing between services, was 12 hours, in which case the pigs were from the second boar. The single litters[2] were sired with approximately equal frequency by the two boars regardless of the time interval, at least up to 12 hours. Nor does the interval between services appear to affect the parentage of pigs in mixed litters.[2] However, a greater proportion of mixed litters resulted from matings with short intervals between services than from those in which the intervals were longer. Among 65 double matings with intervals between services of 5 minutes or less 43 mixed litters were produced. Among 15 litters with intervals of 6 to 20 minutes inclusive between services only 7 were mixed. No mixed litters were produced in 6 cases in which the interval between services was longer than 20 minutes.

ORDER OF MATING IN RELATION TO PARENTAGE OF PIGS

The order of mating within the time elapsing between services (table 1) had no significant relation to the parentage of the pigs produced. Among 40 litters with only 1 sire represented in a litter,[3] the boars used first produced 21 and the boars used last produced 19

[2] The three kinds of litters produced from double matings are designated as follows: Purebred litter, a litter all pigs of which were sired by the boar of the same breed as that of the sow; crossbred litter, a litter all pigs of which were sired by the boar of the breed different from that of the sow; mixed litter, a litter containing pigs sired by both boars; single litter, a litter all pigs of which were sired by one boar, and may be either purebred or crossbred.

[3] In table 1 only 36 litters sired by one boar are shown because the time between services was not recorded for the remaining matings.

litters. However, there was a greater number of litters with all pigs either purebred or crossbred than would be expected on the basis of random fertilization with two kinds of spermatozoa present in equal numbers. The proportions among 105 litters where double mating was used were 24 purebred, 16 crossbred, and 65 mixed litters.

Two possible explanations of this unexpected distribution are: (1) The spermatozoa of the two boars were deposited in different positions in the reproductive tract. Those deposited closer to the oviduct, and consequently to the eggs, would have the first opportunity of fertilizing the eggs. (2) Variation in the relative fertility of the two boars at different services.

While the kinds of litters were not influenced by the order of mating, the kinds of pigs in mixed litters were affected by the order of mating (table 2). In 65 mixed litters containing 637 pigs, 359 were sired by the boar used first and 278 by the boar used last. Assuming numbers of sperm and other conditions to be similar, with random fertilization a ratio of 1:1 in respect to the offspring of the two would be expected. The observed results deviate 40.5 from the expected. The probable error of this ratio is 8.5. $\frac{D}{PE}=4.8$, and indicates a significant departure from the expected. With all litters, both single and mixed, the boars used first sired 546 pigs and those used last sired 402.

Among 637 pigs in the 65 mixed litters, 329 were purebred and 308 were crossbred. The deviation here is 10.5 and $\frac{D}{PE}=1.2$, indicating a close fit to the theoretical expectation. In the matings to produce these 65 litters, boars which would produce purebred pigs were used first 35 times and boars which would produce crossbred pigs were used first 30 times. Since according to these figures, the boars used first have a greater chance of being parents than the boars used last, a correction can be made. On the basis of the foregoing results the first boar has a chance of 359/637 of being the sire of a given pig. Correcting for the five extra matings of boars which would produce purebreds, the ratio becomes 325.8 : 311.2. $\frac{D}{PE}=0.86$, indicating a very close fit to the theoretical expectation.

TABLE 2.—*Number of litters and pigs produced by the first and the second boar*

Matings			Single litters sired by—				Mixed litters sired by both boars		
			First boar		Second boar			Pigs from—	
First boar	Second boar	Sow	Litters	Pigs	Litters	Pigs	Litters	First boar	Second boar
			Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Duroc Jersey	Poland China	Duroc Jersey	2	16	5	35	15	104	72
Poland China	Duroc Jersey	do	5	53	4	20	14	77	56
Do	do	Poland China	10	95	2	7	20	101	82
Duroc Jersey	Poland China	do	4	23	8	62	16	77	68
Total			21	187	19	124	65	359	278

AGE OF BOAR AND NUMBER OF PIGS PRODUCED

Thirteen mixed litters with 125 pigs were produced by double matings in which the boars used first were at least 1½ years older than the boars used last. The first boar sired 62 pigs and the second 73. Sixteen mixed litters with 170 pigs were produced in which the boars used first were at least 1½ years younger than those used last. In this case the first boars sired 103 pigs and the second 67. In mixed litters from boars of the same age (±3 months) 195 pigs were sired by the first boar and 138 by the second. These figures indicate that younger boars tend to produce more pigs in mixed litters than do older boars but, other things being equal, when two boars are used in double matings more pigs are likely to be sired by the first boar than by the second.

SIZE OF SINGLE LETTERS AS COMPARED WITH MIXED LITTERS

The mean litter size of 40 single litters from double matings was $7.78 \pm .36$, whereas in 65 mixed litters with two sires the litter size was $9.82 \pm .24$, a significant difference. $D = 2.04 \pm .43$. The age of the dam, however, influences the size of the litter. The average age of the mothers of the 40 single litters was 1.88 years, and that of the mothers of the 65 mixed litters, 2.14 years. In order to eliminate the effect of age, 40 mixed litters were taken whose mothers were of the same ages as the mothers of the single litters. The results were still significantly in favor of the litters from two males being larger than litters from single males. With the ages the same, the average size of litters with two sires was $9.70 \pm .26$. The difference between this and the size of single litters is $1.92 \pm .44$. $\frac{D}{PE} = 4.36$. The exact cause of this difference is not evident. That it is not due to a higher intrauterine survival of crossbred pigs is indicated by the fact that the 24 purebred single litters had an average litter size of 8.0, while 16 crossbred litters had an average size of 7.4. In these averages, age of sows was not considered, but when only sows of the same ages are used in the computations the average litter sizes for purebreds and crossbreds are 7.4 and 7.0, respectively.

BIRTH WEIGHTS OF PUREBRED AND CROSSBRED PIGS

Birth weights of purebred and crossbred pigs were analyzed in three different ways, taking:

(1) All pigs whether born in single or mixed litters.
(2) The average weight of purebred and of crossbred pigs of the same sex in mixed litters. The average weight of purebreds in a mixed litter was paired with the average weight of the crossbreds and analyzed by Student's method.
(3) Pairs consisting of a purebred and a crossbred pig of the same sex taken at random from each mixed litter and analyzed by Student's method.

By the first method in which all purebred pigs were compared with all crossbred pigs, no significant difference between purebreds and crossbreds was found. The mean birth weight of purebred was $2.62 \pm .02$ pounds and that of the crossbreds was $2.64 \pm .02$.

When the average birth weights of purebred and crossbred pigs of the same sex and litter were compared the only significant difference found was between purebred and crossbred females from Poland China

sows × Poland China and Duroc Jersey boars. In this case the average weight of the purebreds was 2.61±.05 and of the crossbreds 2.90±.06 (table 3). For all purebreds and crossbreds in these mixed litters, the average birth weight of the purebreds is 2.62±.03 and for the crossbreds 2.72±.03. The difference is 0.10±.04, which is not significant.

The third method of analysis was to take pairs, one member of a pair purebred and the other a crossbred of the same sex from the same litter. These pairs were taken at random and the total number was 184. The mean difference is 0.1299 pound in favor of the crossbreds and the value of *P* is 0.9793. The odds are 194 to 1 in favor of the crossbreds. The average birth weights in pounds of the purebreds and crossbreds in these pairs are 2.63 and 2.76, respectively.

TABLE 3.—*Comparison of average birth weights of purebred and crossbred pigs in mixed litters by parentage and sex*

Mating			Males			Females		
First boar	Second boar	Sow	Pairs of averages	Purebred	Crossbred	Pairs of averages	Purebred	Crossbred
			Number	*Pounds*	*Pounds*	*Number*	*Pounds*	*Pounds*
Duroc-Jersey	Poland China	Duroc-Jersey	22	2.55±.084	2.74±.060	22	2.56±.070	2.55±.052
Do	do	Poland China	29	2.73±.065	2.68±.073	28	2.61±.052	2.90±.060

STRENGTH OF PIGS AT BIRTH

At farrowing the pigs were classified in respect to strength as strong, medium, weak, and dead except for those in seven litters early in the experiment. On the basis of the appearance and activity of the pigs at birth 3.7 percent more of the crossbreds than of the purebreds were graded strong and also 2.4 percent less of the crossbreds were in the medium class (table 4). The percentage of weak pigs was slightly higher for purebreds, though the percentage of purebreds farrowed dead was lower.

MORTALITY BEFORE VACCINATION

The average age at which the pigs were vaccinated was 38 days. Owing to the presence of some undiagnosed disease in the herd, mortality was exceptionally high one year. In mixed litters (table 5) the mortality of the crossbred pigs was 39.6 percent while that of the purebreds was 48.6 percent. In single litters the mortality was greater in the crossbreds than in the purebreds by 10.7 percent. When all purebred and crossbred pigs are considered, the mortalities in percent are 43.3 and 41.1, respectively.

RESULTS OF FEEDING TESTS

Purebred and crossbred pigs from different dams were not included in the feeding trials, except in one instance, because environmental differences among such pigs are greater than among purebred and crossbred pigs farrowed in the same litter. Such environmental

differences might mask the real effects of cross-breeding. Feeding tests were conducted with only 3 of the 5 crops of pigs. While there were 65 mixed litters at weaning time, the number for 2 years, containing both purebred and crossbred pigs, was considered too small for reliable feeding tests. For this reason only 20 mixed litters were available for the feeding trials.

TABLE 4.—*Strength at birth of purebred and crossbred pigs farrowed in mixed litters*

Condition of new-born animal	Purebred		Crossbred	
	Number	*Percent*	*Number*	*Percent*
Strong	195	68.5	200	72.2
Medium	40	14.0	32	11.6
Weak	36	12.6	28	10.1
Dead	14	4.9	17	6.1
Total	285	100.0	277	100.0

TABLE 5.—*Number and percentage of pigs alive at vaccination at an average age of 38 days*

Born in—	Pigs farrowed		Pigs alive at vaccination			
	Purebred	Crossbred	Purebred		Crossbred	
	Number	*Number*	*Number*	*Percent*	*Number*	*Percent*
Mixed litters	329	308	169	51.4	186	60.4
Single litters	193	118	127	65.8	65	55.1
Total	522	426	296	56.7	251	58.9

Initial weights, average daily gains, and final weights obtained from the feeding trials may be analyzed in various ways. The averages of these measurements for purebreds and crossbreds may be compared directly by including all purebreds and crossbreds used in the experiment (tables 6 and 7). A more critical analysis may be made by comparing the average of the purebreds with that of the crossbreds in each litter. By this method many environmental factors which might otherwise disturb the results are eliminated. The members of the pair have the same mother and have been subjected to the same maternal conditions, which are known to be important. They are of the same age when put into the feed lots. Table 8 gives the results of the statistical analysis of pairs of averages from 20 litters. These pairs were analyzed by Student's method.

The average initial weight of the purebred pigs from the 20 mixed litters as the pigs were started on the feeding trial portion of the experiment was 65.3 pounds. The average weight of the crossbred pigs of the same litters at the same time was 68.4 pounds. The difference is not significant.

The daily rates of gain for averages of purebreds and crossbreds were 1.59 and 1.65 pounds, respectively, again not significantly different.

While on the feeding tests the animals were in groups according to parentage and, therefore, the individual feed consumption is not available. The feed consumption by lots of purebreds and crossbreds is given in tables 6 and 7. The amount of feed consumed per unit of gain in two of the three feeding trials was in favor of the crossbreds

and one was in favor of the purebreds. If all purebreds are compared with all crossbreds the feed consumption per 100 pounds of gain was 409 pounds for the purebreds and 402 for the crossbreds. This is not a significant difference.

TABLE 6.—*Weights, gains, and feed consumption of purebred and crossbred pigs for 3 years, 1925, 1927, and 1929*

Item	1925				From mixed litters, 1927				From mixed litters, 1929			
	Purebred litter	Purebreds from mixed litters	Crossbreds from mixed litters	Crossbred litter	Purebred Duroc Jerseys	Crossbreds by Duroc Jersey sire	Crossbreds by Poland China sire	Purebred Poland Chinas	Purebred Duroc Jerseys	Crossbreds by Duroc Jersey sire	Crossbreds by Poland China sire	Purebred Poland Chinas
Pigs started—number	7	5	15	7	8	12	4	18	16	13	14	13
Pigs finished—do	6	5	14	7	8	11	4	18	15	13	14	13
Average age at start—days	75	77	78	78	111	107	112	109	130	130	131	132
Average time required to finish—days	96	102	94	85	98	98	63	84	71	71	77	77
Average initial weight—pounds	51	39	47	55	60	64	96	72	67	72	67	72
Average final weight—pounds	204	200	205	205	203	202	208	198	196	200	204	197
Average daily gain—pounds	1.59	1.57	1.68	1.77	1.45	1.38	1.79	1.50	1.79	1.80	1.78	1.62
Feed consumed per 100 pounds of gain—pounds	391	401	378	400	423	422	406	427	389	398	411	410

TABLE 7.—*Summary of weights, gains, and feed consumption of purebred and crossbred pigs for 3 years, 1925, 1927, and 1929*

Item	1925		1927	
	Purebred	Crossbred	Purebred	Crossbred
Pigs—number	11	21	26	15
Average initial weight—pounds	47	53	69	70
Average time required to finish—days	99	91	88	89
Average daily gain—pounds	1.59±.031	1.71±.018	1.49±.055	1.50±.055
Feed consumed per 100 pounds of gain—do	396	385	426	418

Items	1929		Totals	
	Purebred	Crossbred	Purebred	Crossbred
Pigs—number	28	27	65	63
Average initial weight—pounds	70	70	65	64
Average time required to finish—days	75	75	84	83
Average daily gain—pounds	1.71±.022	1.79±.025	1.60±.017	1.69±.026
Feed consumed per 100 pounds of gain—do	399	405	409	402

TABLE 8.—*Initial weights, daily gain, and 6-month weights of purebred and crossbred pigs*

[Average of purebreds paired with average of crossbreds in same litter (20 pairs)]

Item	Purebred	Crossbred	*Z*	Probability
	Pounds	*Pounds*		
Initial weight	65.3	68.4	0.22	4.4:1
Average daily gain	1.59	1.65	.22	4.4:1
Last weight	179.1	185.6	.22	4.4:1

Because all pigs of a litter did not finish the feeding test at the same time (they were removed when the individual reached a weight of 200 pounds) their final weights were not taken at a uniform age. In order to compare the average weight of all purebred pigs of a litter with that of all crossbred pigs of the same litter at the same age, it was necessary to select weights which were taken at the same time, but before any of the pigs had been removed from the experiment. The average of the 20-litter averages for purebred pigs was 179.1 pounds and for the crossbreds 185.6. Again the difference is not significant. A summary of these results is given in table 8.

In all comparisons of purebred and crossbred animals in this experiment, including weight at birth, mortality before vaccination, initial weight, rate of gain, feed consumption per 100 pounds gain, and weight at approximately 6 months of age, the only one significantly in favor of the crossbreds is birth weight. The others are in favor of the crossbreds but the difference is in no case significant. One might inquire into the probability of all or several measurements being in favor of the crossbreds when no one is significant. The question, however, is not one of simple probability because of the correlations existing among such things as rate of gain, economy of gain, and initial weights.

The literature on cross-breeding swine is by no means consistent in ascribing beneficial results to cross-breeding. As long as such a condition exists it would seem that a problem of major importance is to learn more concerning the nature of heterosis or hybrid vigor in order that predictability of cross-breeding results might be attained. The system of double mating provides a refinement in experimental technique which this problem in its present state greatly needs.

SUMMARY

Double matings were used with Duroc Jersey and Poland China swine to produce litters that contained both purebred and crossbred pigs.

A significantly larger number of pigs were produced in litters sired by two boars (mixed litters) than in litters sired by a single boar (purebred or crossbred litters).

The birth weights of purebred and crossbred pigs were subjected to three methods of analysis to determine whether the differences between them were significant. By the method considered best adapted to the problem, a small but significant difference in favor of the crossbreds was demonstrated.

Among pigs farrowed alive the strength gradings were slightly in favor of the crossbreds, but a slightly larger percentage of crossbred pigs were farrowed dead.

Mortality before vaccination was slightly less in crossbreds than in purebreds.

Small differences in favor of crossbreds were found in respect to weight at beginning of feeding test, daily rate of gain, feed per 100 pounds of gain, and weight near market age, but these differences were not statistically significant.

U. S. GOVERNMENT PRINTING OFFICE: 1940